Hydrological Summary

for the United Kingdom

September 2023

General

The first half of September was characterised by high pressure and temperatures, and the second half by autumnal wind and rain. Temperatures exceeded 30°C each day from 4th-10th (the longest run of consecutive days seen in September) contributing to the joint warmest September for the UK on record (equalling the previous maximum established in 2006, in a series of 140 years). Rainfall was above average, with intense but localised thunderstorms giving way to more widespread outbreaks of rain. Accordingly, many river flows were above average. Groundwater levels continued to recede at most sites, with levels mainly normal to above normal; a notable exception was the ongoing low levels in the Devonian sandstones of Scotland. Reservoir stocks at the national scale increased relative to average and remained healthy (at least 10% above average for Scotland, Northern Ireland and England). Stocks at Loch Thom saw recovery, but those at and Celyn & Brenig, Colliford, Roadford and Ardingly remained at least 10% below average. Water resources are healthy and the outlook for the next three months for most of the UK is for normal to above normal flows and groundwater levels (with the focus turning towards flood-risk in early October in Scotland). However, where impoundments have below average stocks, and in localised areas with below normal groundwater levels and river flows, continued vigilance will be required through the autumn months.

Rainfall

The first half of September was dominated by anticyclonic conditions, and largely dry except for thunderstorms that brought heavy rain, most notably in Northern Ireland on the 7th, and northern and eastern England on the 10th (when 60mm was recorded at Shap, Cumbria). From 11th-16th conditions began to turn unsettled, with outbreaks of more persistent rain, and on the 17th, very heavy thundery rain caused localised impacts, including flooding of around 100 properties in the south-west and closure of the airport in Exeter (where 64mm of rain were recorded). Unsettled conditions dominated the rest of the month, with frontal rain and strong winds associated with Atlantic low pressure systems. On 19th, 117mm of rain was recorded at Honister Pass, Cumbria and the 20th saw more than 500 properties in Wales without power. On the 24th, heavy rain affected the north-west, and on the 27th-28th, named storm 'Agnes' caused some travel disruption in the north-west and Northern Ireland. Total September rainfall was 131% of average, with anomalies greatest in the west (exceeding 170% in parts of Northern Ireland, north-west and south-west England and locally elsewhere), and deficits greatest in the south-east (with less than 50% of average). Only Southern region saw below average rainfall (88% of average), whilst some northern and western regions received more than 150% of average (Northern Ireland, Tay and Solway). Following a wet July, 3-month accumulations (July-September) were above average in all regions (notably so in Northern Ireland and North West England with more than 150% of average), but over the hydrological year as a whole, small deficits in northern Scotland remained. In Northern Ireland, the 3-month period (July-September) was the third wettest on record (in a series from 1890).

River Flows

River flows during the first half of September receded, although without becoming noteworthy in magnitude (except for the Waveney which recorded new daily minima from 6th-11th in a series from 1963). There were responses to local rainfall from 10th-12th (predominantly on rivers in the north), and on the 17th (most notably in the south-west, where there were reports that flooding from local watercourses affected Dawlish, Devon). The following few days saw the most widespread and marked increases of the month, taking many river flows from below to well above average. Peak flows ranking in the top three for September were recorded on the 19th (on the Conwy and Welsh Dee), and the 20th (on the Leven and Tawe, with the latter seeing its third highest peak flow recorded in any month), all in series of 50 years or more. Thereafter, flows on many rivers, including large catchments, receded towards average. In the west, however, high flows were sustained by further peaks on the 24th, the 28th (when the Lower Bann, responding to storm 'Agnes', recorded its third highest September peak flow in a series from 1980), and the 30th (most notably on Welsh rivers). Mean September flows were normal in Scotland, and typically normal or above normal elsewhere (notably so for rivers in the west e.g. Eden, Erch and Tone, which each recorded around twice their mean monthly flow and ranked in the top five for September in series of 50 years or more). Mean flows for July-September were similarly normal or above normal, with exceptions in East Anglia (e.g. the Wensum and Waveney). Over the same 3-month period, Northern Ireland mean outflows ranked third in a series from 1980.

Soil Moisture and Groundwater

Soil wetness increased in many areas but remained below field capacity in the south-east. Groundwater levels continued to recede in the majority of Chalk sites, and levels remained mainly in the normal range. Significant recharge occurred at Killyglen from mid-month and levels (which were in the normal range in August) became exceptionally high. Less dramatic signs of a probable start to the recharge season were observed in the latter part of the month at Wetwang, Rockley and West Woodyates. Levels remained below normal at Dial Farm in East Anglia. In the Jurassic limestones, levels fell but remained in the above-normal range at New Red Lion and rose from mid-month but remained notably high at Ampney Crucis. Levels fell and remained in the normal range in the Magnesian Limestone. Recharge was recorded from mid-month in the Carboniferous Limestone of south Wales, where levels remained in the normal range. Data were not available for Alstonfield or for several sites in the Permo-Triassic Sandstones. The remaining sites in this aquifer are widely geographically distributed and showed distinct behaviours in September. At Skirwith, levels rose throughout much of September, remaining above normal. Levels were stable and remained in the normal range at Llanfair D.C. in north Wales. A recharge event was recorded mid-month at Bussels No.7a and levels ended the month notably high. The recession continued in the Upper Greensand at Lime Kiln Way where levels remained in the normal range. A new September minimum was recorded in the Devonian sandstone at Feddan Junction (in a 20-year series). Levels fell and remained below normal at Easter Lathrisk. At Royalty Observatory (Fell Sandstone), levels fell and remained in the normal range.

National Hydrological Monitoring Programme | UK Centre for Ecology & Hydrology | BGS British Geological Survey

Rainfall . . . Rainfall . . .

Met Office

Rainfall accumulations and return period estimates

Percentages are from the 1991-2020 average.

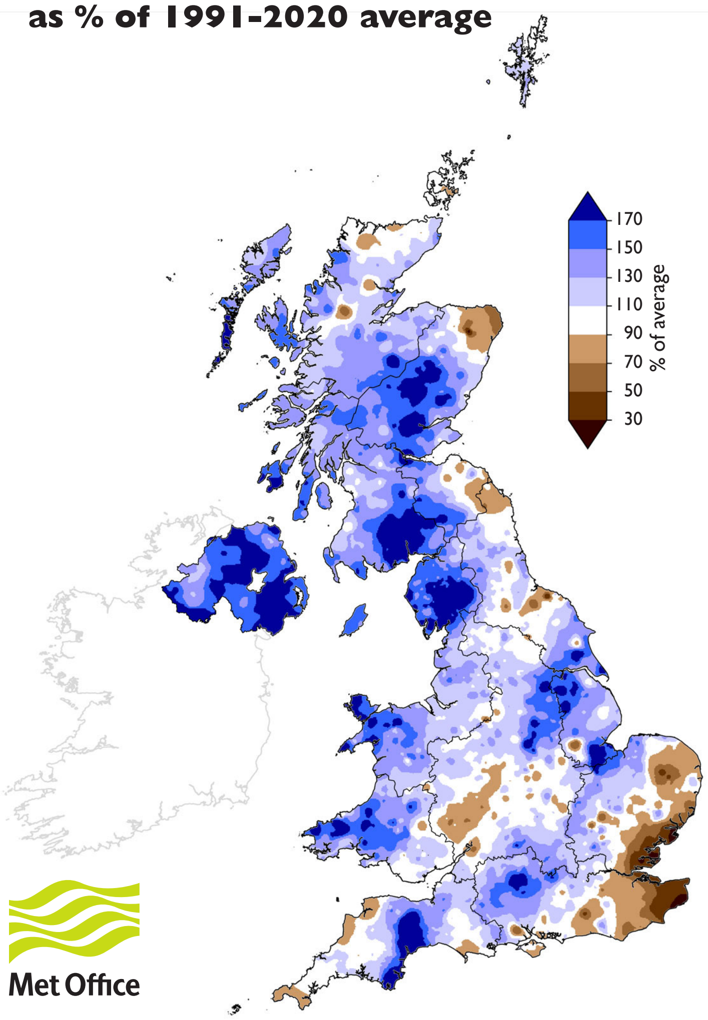
Region	Rainfall	Sep 2023	Aug23 – Sep23	RP	Jul23 – Sep23	RP	Apr23 – Sep23	RP	Oct22 – Sep23	RP
United	mm	**119**	208		349		510		1241	
Kingdom	%	**131**	113	2-5	130	8-12	105	2-5	107	10-15
England	mm	**82**	154		274		418		984	
	%	**119**	107	2-5	131	5-10	108	2-5	114	10-15
Scotland	mm	**168**	271		426		608		1560	
	%	**136**	111	2-5	123	5-10	98	2-5	99	2-5
Wales	mm	**156**	275		452		611		1599	
	%	**139**	123	2-5	140	8-12	104	2-5	110	5-10
Northern	mm	**145**	272		457		668		1330	
Ireland	%	**166**	145	8-12	165	30-50	132	50-80	115	60-90
England &	mm	**92**	170		298		444		1068	
Wales	%	**123**	111	2-5	133	5-10	107	2-5	113	10-15
North West	mm	**157**	270		479		647		1466	
	%	**146**	124	2-5	151	20-30	118	5-10	114	25-40
Northumbria	mm	**83**	169		297		425		927	
	%	**114**	110	2-5	130	5-10	101	2-5	102	2-5
Severn-Trent	mm	**74**	128		242		383		877	
	%	**116**	97	2-5	121	2-5	101	2-5	109	5-10
Yorkshire	mm	**84**	169		306		436		961	
	%	**119**	114	2-5	141	8-12	109	2-5	110	5-10
Anglian	mm	**57**	109		194		317		681	
	%	**108**	96	2-5	115	2-5	101	2-5	108	2-5
Thames	mm	**69**	130		219		361		874	
	%	**123**	110	2-5	128	2-5	110	2-5	121	10-15
Southern	mm	**55**	124		207		351		1006	
	%	**88**	99	2-5	116	2-5	105	2-5	123	10-20
Wessex	mm	**82**	156		284		448		1140	
	%	**123**	112	2-5	142	5-10	118	5-10	126	30-50
South West	mm	**108**	202		358		539		1437	
	%	**122**	111	2-5	135	5-10	110	2-5	115	10-15
Welsh	mm	**148**	264		434		591		1544	
	%	**138**	122	2-5	139	8-12	104	2-5	110	5-10
Highland	mm	**185**	315		471		662		1734	
	%	**125**	113	2-5	122	5-10	94	2-5	94	2-5
North East	mm	**103**	177		293		451		1050	
	%	**124**	102	2-5	114	2-5	95	2-5	99	2-5
Tay	mm	**160**	251		406		580		1470	
	%	**158**	120	2-5	133	5-10	104	2-5	106	5-10
Forth	mm	**134**	212		351		494		1275	
	%	**142**	108	2-5	121	5-10	95	2-5	103	5-10
Tweed	mm	**106**	197		335		459		1125	
	%	**131**	113	2-5	129	5-10	98	2-5	104	5-10
Solway	mm	**193**	276		477		664		1705	
	%	**161**	112	2-5	133	5-10	104	2-5	108	15-25
Clyde	mm	**210**	319		502		729		1864	
	%	**141**	108	2-5	119	5-10	99	2-5	99	2-5

% = percentage of 1991-2020 average *RP = Return period*

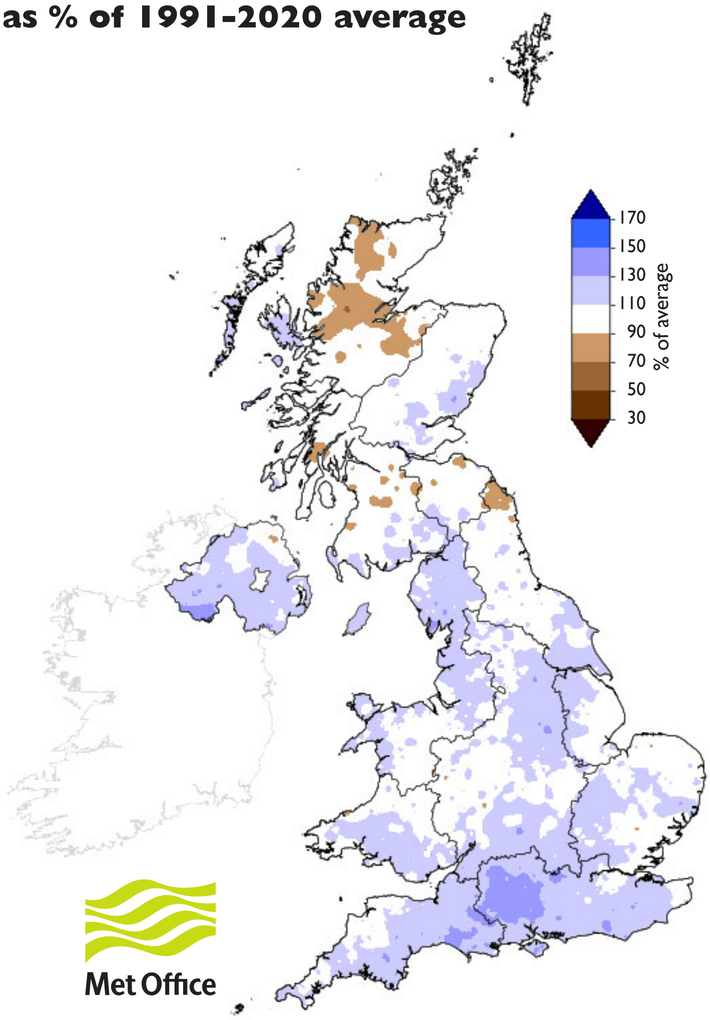
Important note: Figures in the above table may be quoted provided their source is acknowledged. Where appropriate, specific mention must be made of the uncertainties associated with the return period estimates. The RP estimates are based on data provided by the Met Office and reflect climatic variability since 1836; they also assume a stable climate. The quoted RPs relate to the specific timespans only; for the same timespans, but beginning in any month the RPs would be substantially shorter. The timespans featured do not purport to represent the critical periods for any particular water resource management zone. For hydrological or water resources assessments of drought severity, river flows and/or groundwater levels normally provide a better guide than return periods based on regional rainfall totals. Note that precipitation totals in winter months may be underestimated due to snowfall undercatch. All monthly rainfall totals since January 2023 are provisional. Source: Data from HadUK-Grid dataset at 1km resolution v1.2.0.0.

Rainfall . . . Rainfall . . .

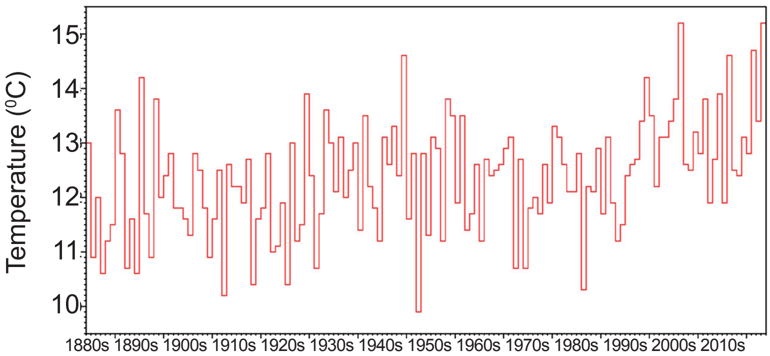
September 2023 rainfall as % of 1991-2020 average



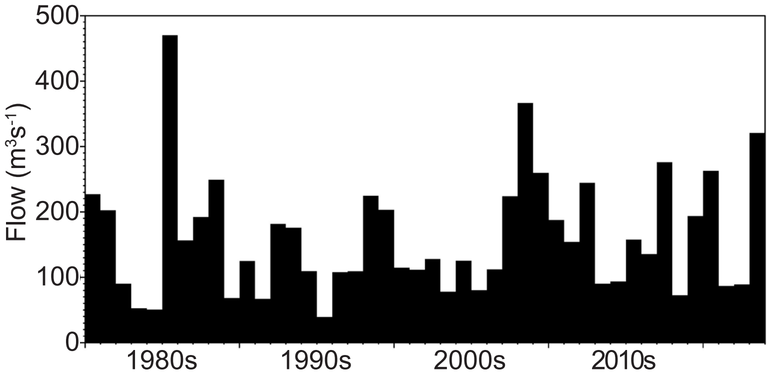
October 2022 - September 2023 rainfall as % of 1991-2020 average



September mean temperature for the United Kingdom



July - September mean outflows for Northern Ireland



UK Hydrological Outlook

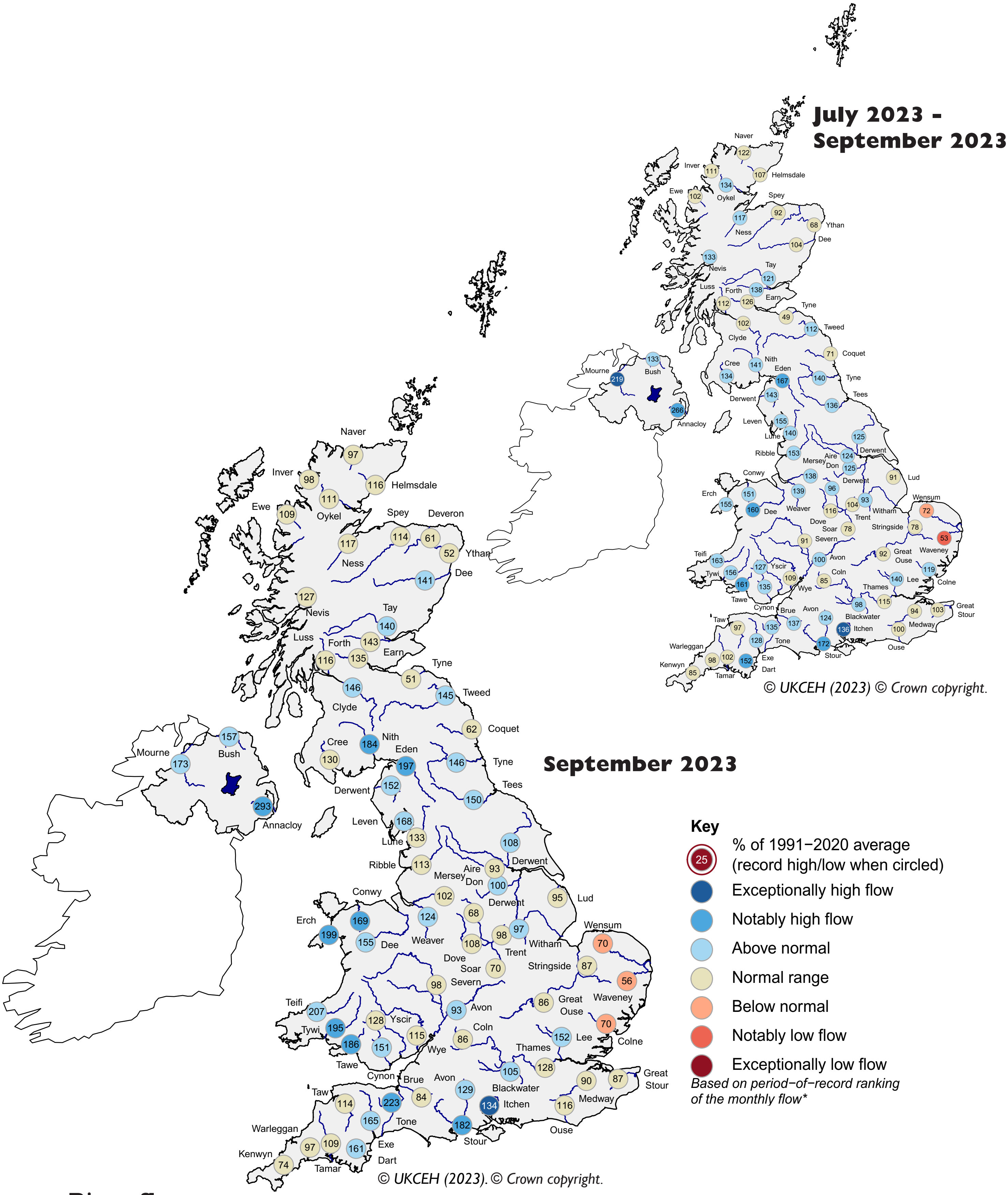
The Hydrological Outlook provides an insight into future hydrological conditions across the UK. Specifically it describes likely trajectories for river flows and groundwater levels on a monthly basis, with particular focus on the next three months.

The complete version of the Hydrological Outlook UK can be found at: www.hydoutuk.net/latest-outlook/

Period: **from October 2023**
Issued: **10.10.2023**
using data to the end of September 2023

The outlook for October is for normal to above normal river flows for most of the UK. In parts of East Anglia and Kent, river flows are likely to be normal to below normal. Elsewhere, in Scotland, flows are likely to be above normal, and exceptionally so in some cases. For groundwater, normal to above normal levels are expected across the country. For October-December, the outlook is for normal to above normal river flows and groundwater levels across the UK, although some below normal river flows may persist in East Anglia.

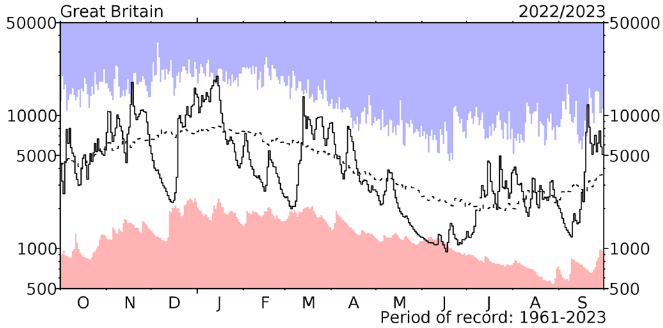
River flow ... River flow ...

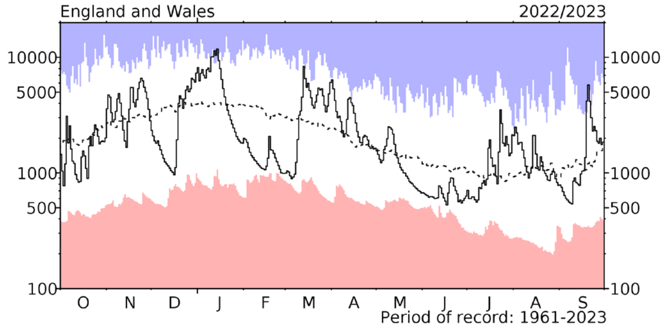


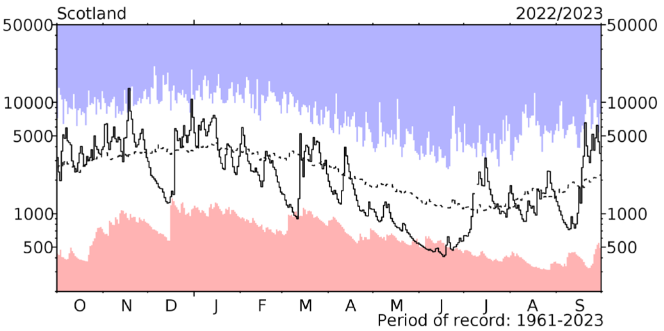
River flows

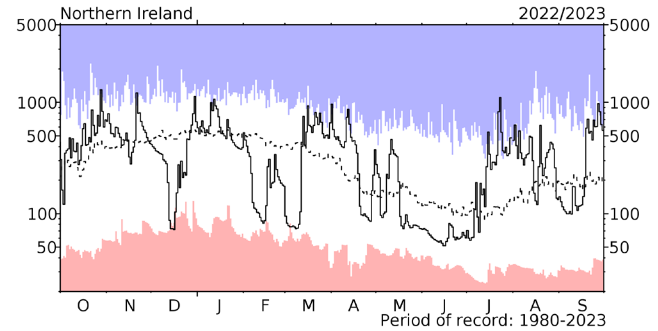
*Comparisons based on percentage flows alone can be misleading. A given percentage flow can represent extreme drought conditions in permeable catchments where flow patterns are relatively stable but be well within the normal range in impermeable catchments where the natural variation in flows is much greater. The categories of the spots are based on the full period-of-record data whereas the percentages are based on the 1991-2020 averaging period for consistency between rainfall and river flows. Percentages may be omitted where flows are under review.

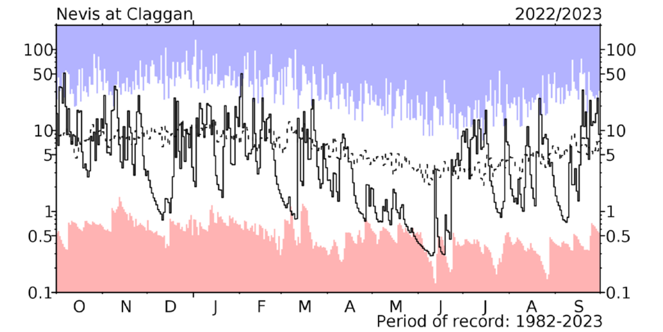
River flow . . . River flow . . .

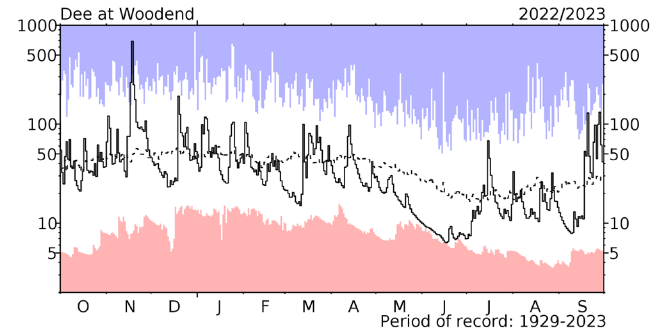


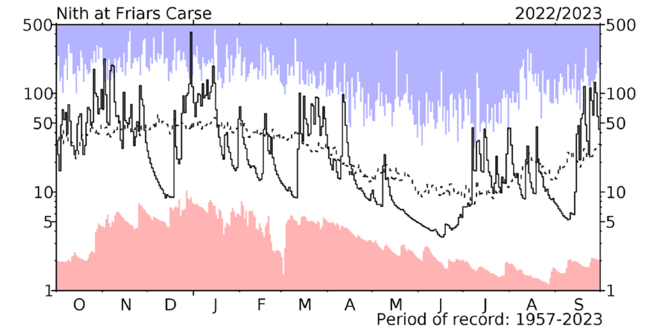


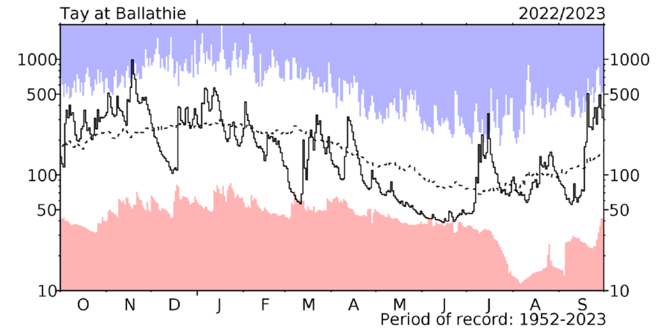


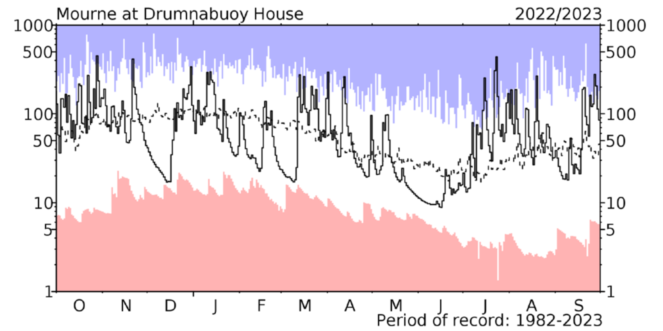


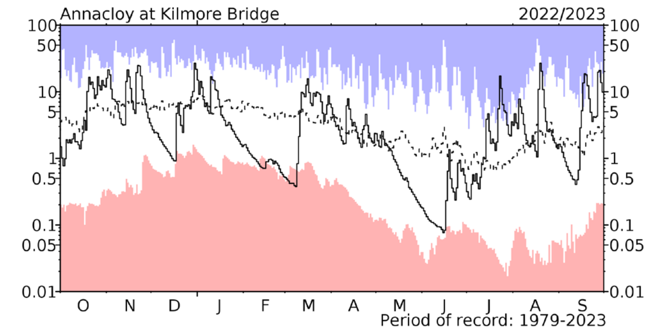






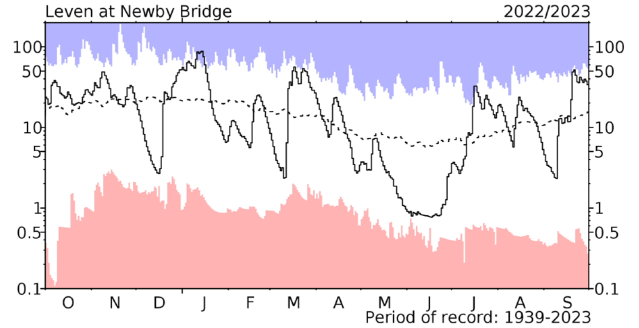


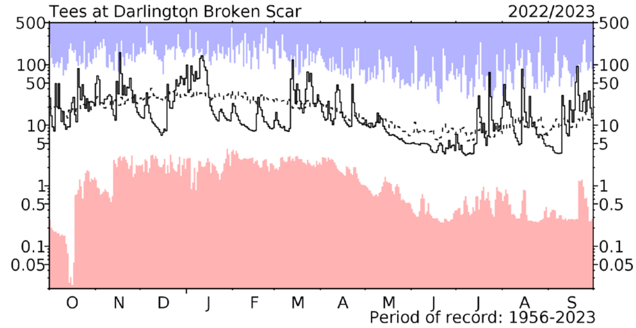


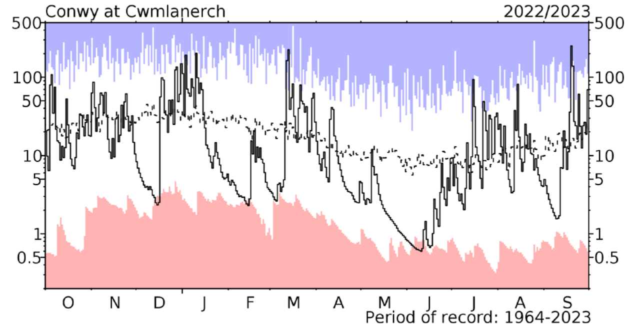


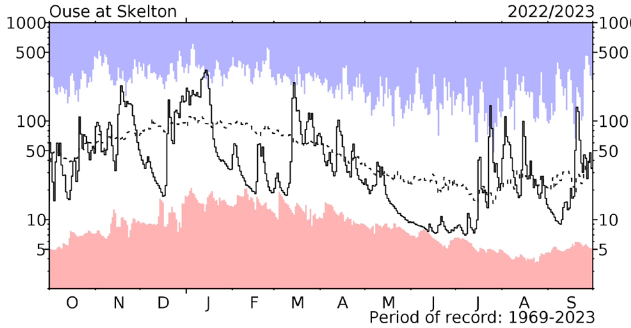
River flow hydrographs

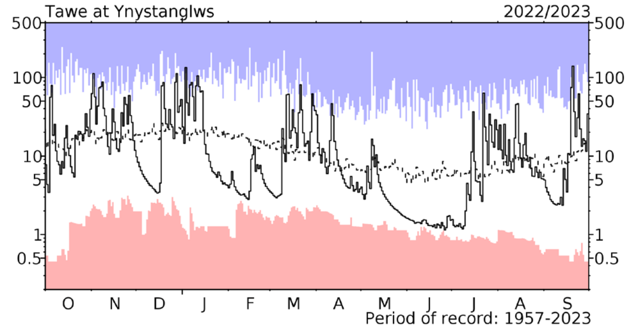
*The river flow hydrographs show the daily mean flows (measured in m^3s^{-1}) together with the maximum and minimum daily flows prior to October 2022 (shown by the shaded areas). Daily flows falling outside the maximum/minimum range are indicated where the bold trace enters the shaded areas. The dashed line represents the period-of-record average daily flow.

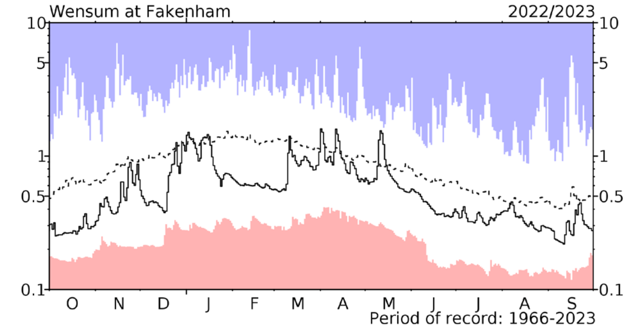

Leven at Newby Bridge
2022/2023
Period of record: 1939-2023

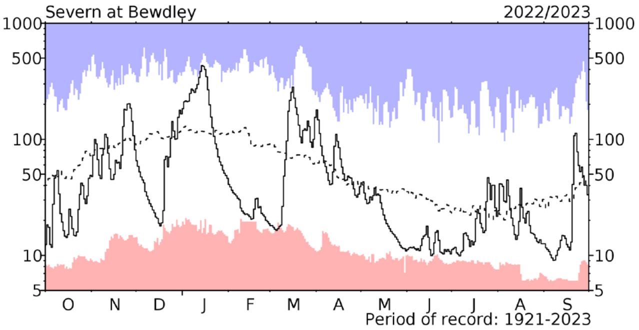

Tees at Darlington Broken Scar
2022/2023
Period of record: 1956-2023

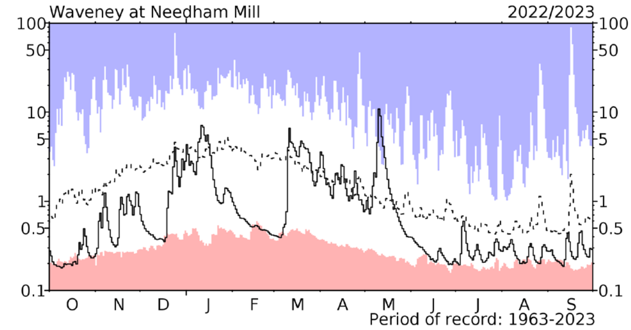

Conwy at Cwmlanerch
2022/2023
Period of record: 1964-2023

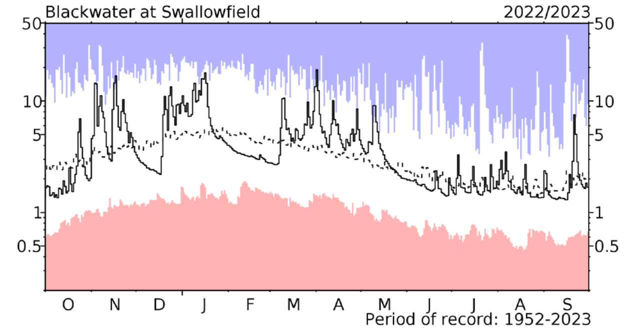

Ouse at Skelton
2022/2023
Period of record: 1969-2023

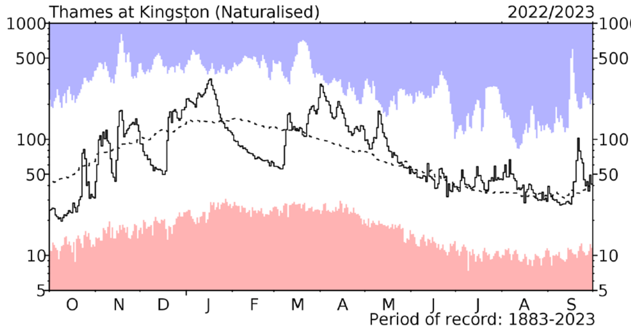

Tawe at Ynystanglws
2022/2023
Period of record: 1957-2023

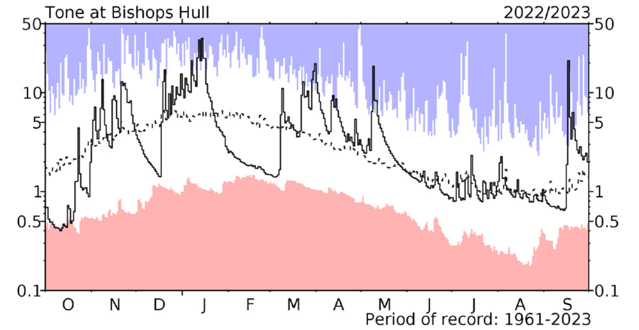

Wensum at Fakenham
2022/2023
Period of record: 1966-2023

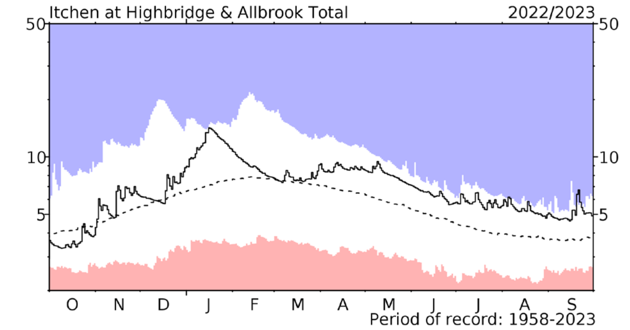

Severn at Bewdley
2022/2023
Period of record: 1921-2023

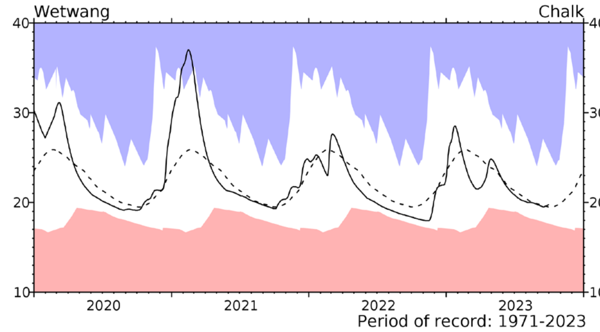

Waveney at Needham Mill
2022/2023
Period of record: 1963-2023

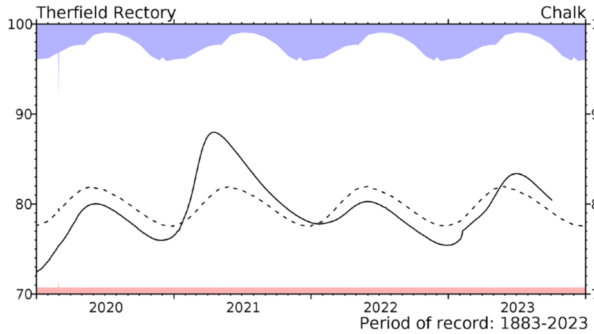

Blackwater at Swallowfield
2022/2023
Period of record: 1952-2023

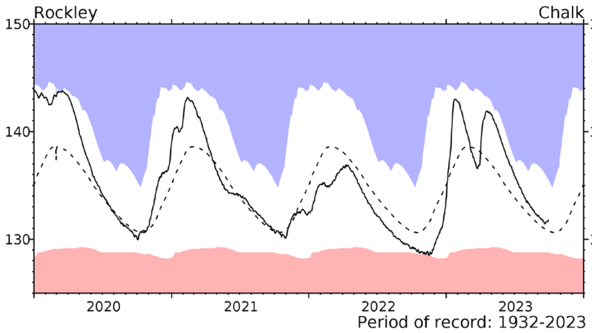

Thames at Kingston (Naturalised)
2022/2023
Period of record: 1883-2023

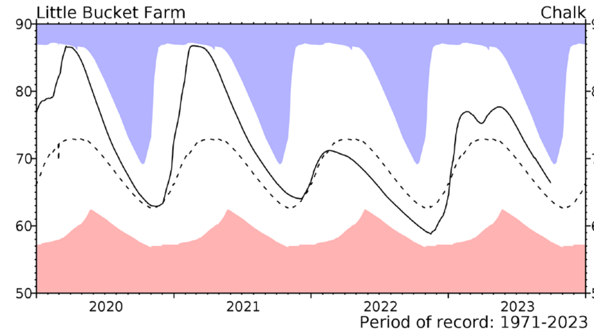

Tone at Bishops Hull
2022/2023
Period of record: 1961-2023

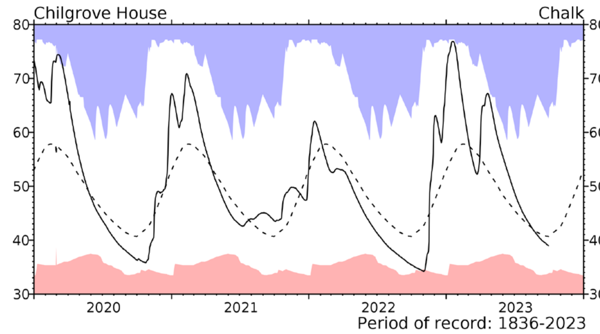

Itchen at Highbridge & Allbrook Total
2022/2023
Period of record: 1958-2023

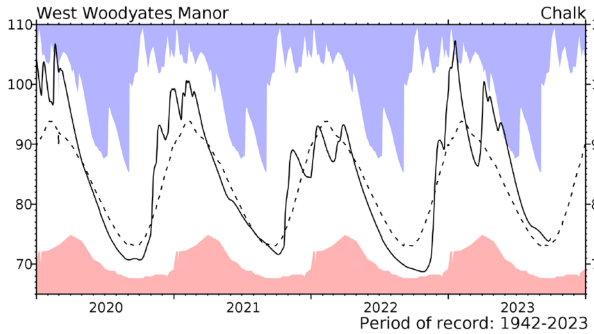


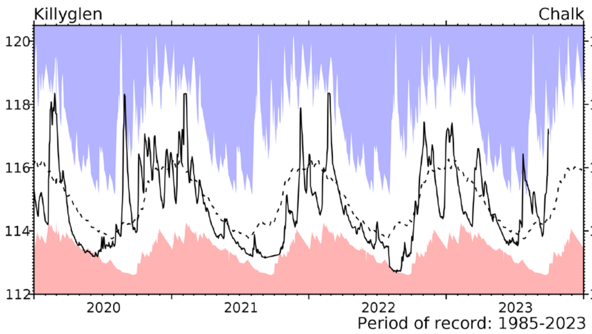


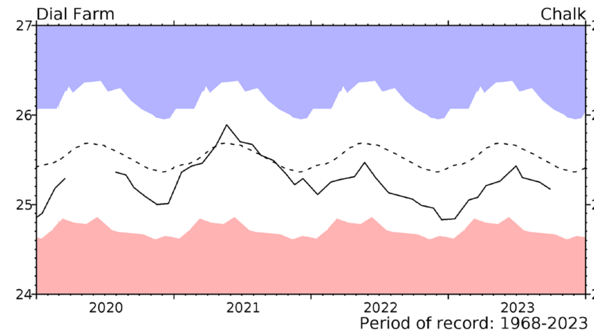


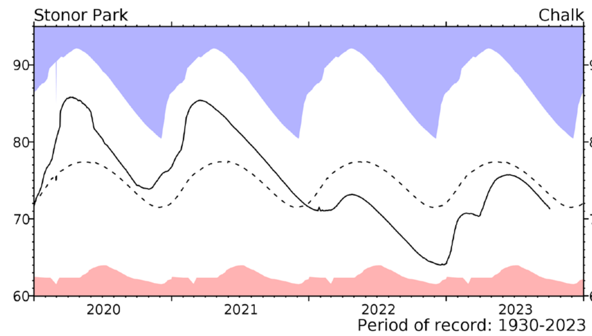


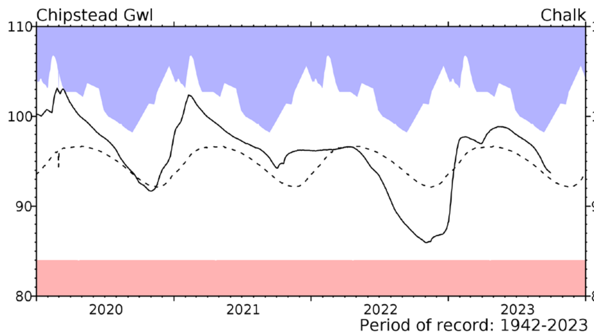






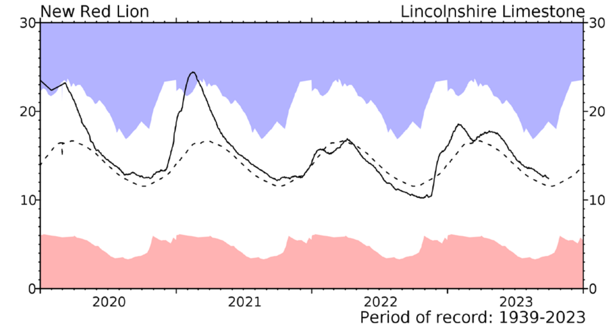


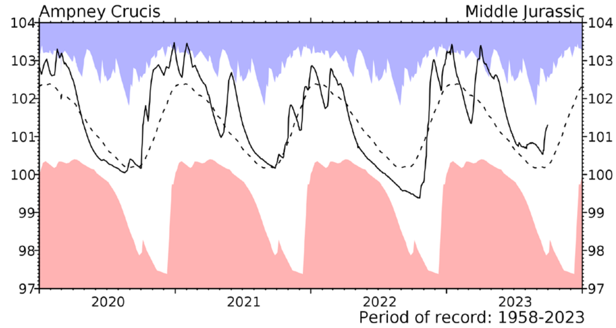


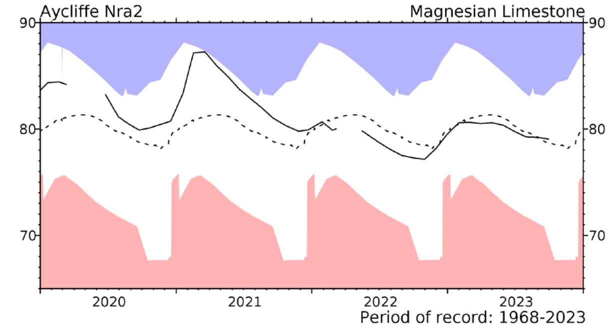


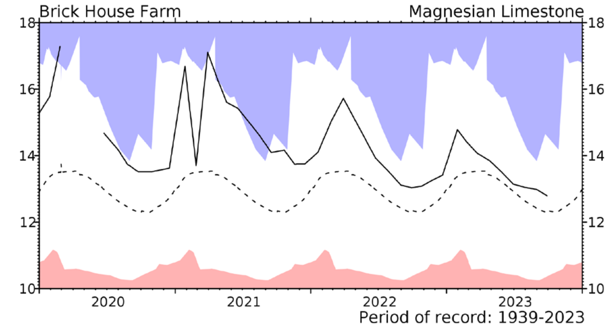
Groundwater levels (measured in metres above ordnance datum) normally rise and fall with the seasons, reaching a peak in the spring following replenishment through the winter (when evaporation losses are low and soil moist). They decline through the summer and early autumn. This seasonal variation is much reduced when the aquifer is confined below overlying impermeable strata. The monthly mean and the highest and lowest levels recorded for each month are calculated with data from the start of the record to the end of 2019. Note that most groundwater levels are not measured continuously and, for some index wells, the greater frequency of contemporary measurements may, in itself, contribute to an increased range of variation.

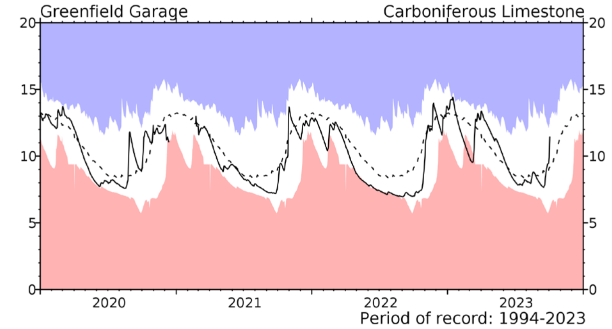
Groundwater ... Groundwater

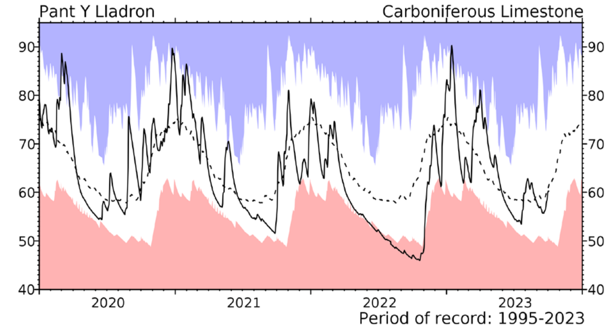


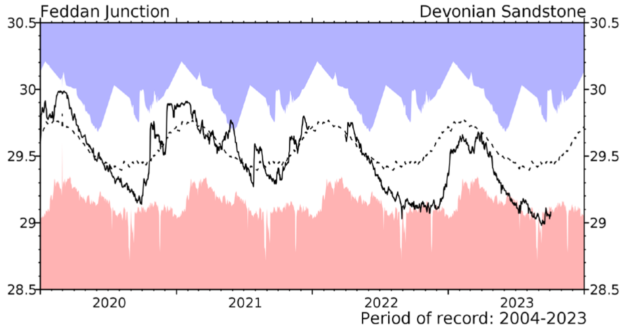


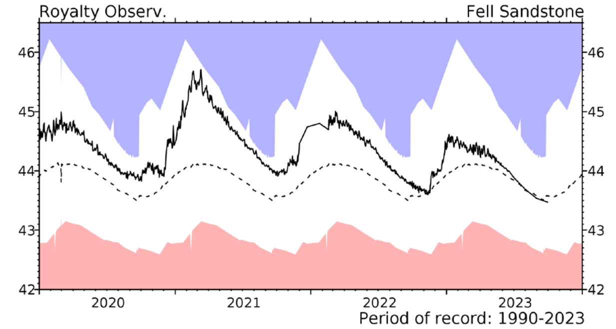


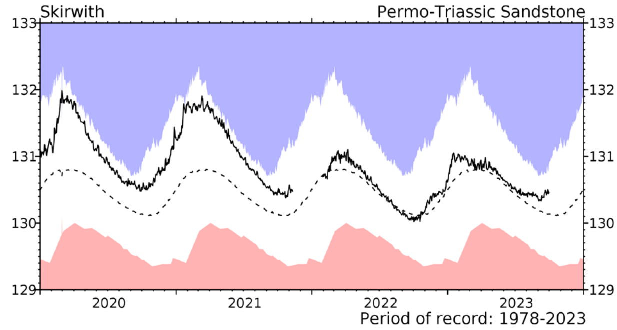


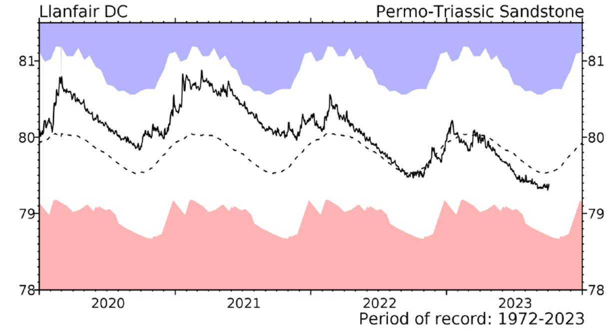


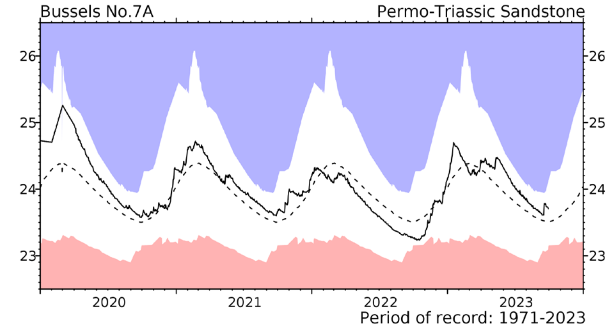


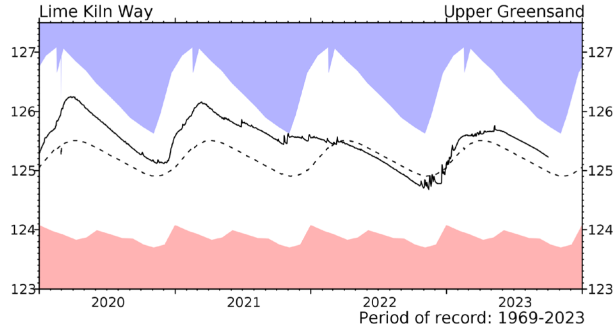












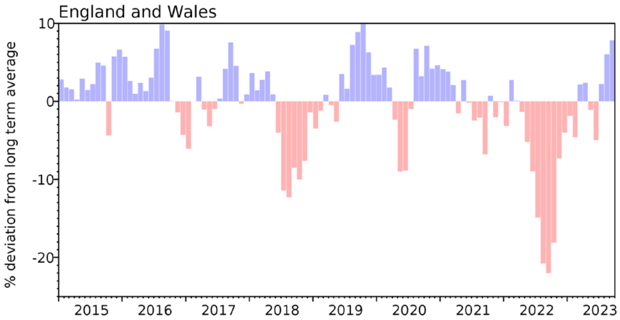
Groundwater...Groundwater

Groundwater levels - September 2023

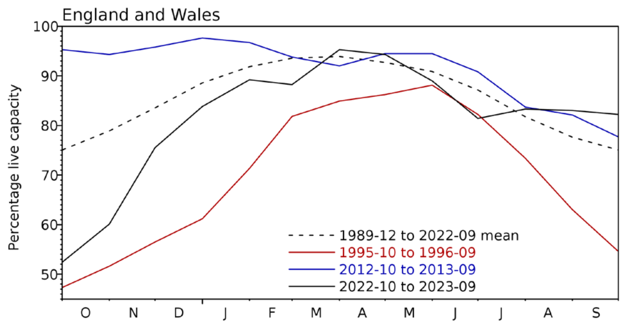
The calculation of ranking has been modified from that used in summaries published prior to October 2012. It is now based on a comparison between the most recent level and levels for the same date during previous years of record. Where appropriate, levels for earlier years may have been interpolated. The rankings are designed as a qualitative indicator, and ranks at extreme levels, and when levels are changing rapidly, need to be interpreted with caution.

Reservoirs . . . Reservoirs . . .

Guide to the variation in overall reservoir stocks for England and Wales



Comparison between overall reservoir stocks for England and Wales in recent years



Percentage live capacity of selected reservoirs at end of month

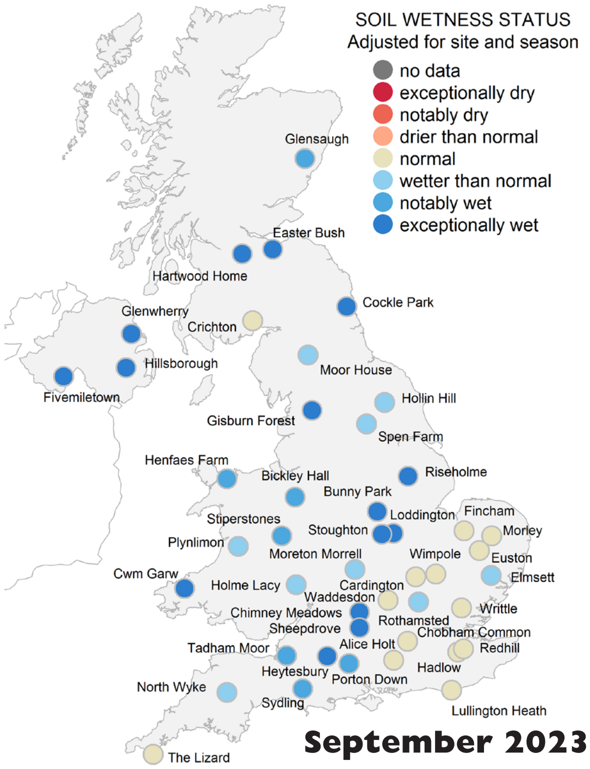
Area	Reservoir		Capacity (Ml)	2023 Jul	2023 Aug	2023 Sept	Sep Anom.	Min Sep	Year* of min	2022 Sep	Diff 23-22
North West	N Command Zone	•	124929	68	73	76	18	13	1995	38	38
	Vyrnwy		55146	87	97	95	25	26	1995	37	58
Northumbrian	Teesdale	•	87936	76	87	98	27	31	1995	79	19
	Kielder		(199175)	98	85	85	0	59	1989	88	-3
Severn-Trent	Clywedog		49936	91	97	89	16	24	1989	40	49
	Derwent Valley	•	46692	79	79	71	8	24	1989	29	42
Yorkshire	Washburn	•	23373	78	82	81	14	24	1995	28	52
	Bradford Supply	•	40942	73	76	74	7	15	1995	28	47
Anglian	Grafham		(55490)	94	93	90	7	46	1997	58	32
	Rutland		(116580)	91	87	85	5	61	1995	70	15
Thames	London	•	202828	97	96	94	17	53	1997	60	34
	Farmoor	•	13822	99	99	96	6	54	2003	63	33
Southern	Bewl		31000	87	82	71	8	32	1990	48	23
	Ardingly		4685	77	62	46	-17	21	2020	25	21
Wessex	Clatworthy		5662	73	68	75	19	25	2003	30	45
	Bristol	•	(38666)	81	78	71	9	31	1990	46	25
South West	Colliford		28540	57	56	52	-15	38	2006	38	14
	Roadford		34500	57	55	54	-13	20	2022	20	34
	Wimbleball		21320	75	73	74	11	23	2022	23	52
	Stithians		4967	73	61	56	0	19	2022	19	38
Welsh	Celyn & Brenig	•	131155	71	68	67	-13	39	1989	46	21
	Brianne		62140	90	100	100	13	48	1995	49	51
	Big Five	•	69762	73	73	71	2	19	1995	32	39
	Elan Valley	•	99106	76	78	85	11	31	2022	31	54
Scotland(E)	Edinburgh/Mid-Lothian	•	97223	87	89	92	14	43	1998	71	21
	East Lothian	•	9317	89	92	91	8	52	1989	67	24
Scotland(W)	Loch Katrine	•	110326	85	84	93	18	41	2021	75	18
	Daer		22494	77	84	89	11	32	1995	70	19
	Loch Thom		10721	70	59	73	-9	40	2021	69	4
Northern Ireland	Total+	•	56800	92	97	99	24	29	1995	69	30
	Silent Valley	•	20634	92	99	100	29	27	1995	64	36

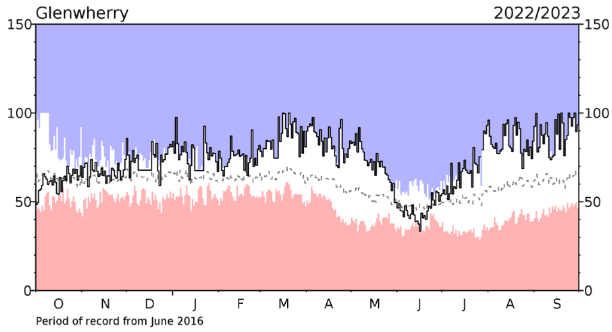
( ) figures in parentheses relate to gross storage • denotes reservoir groups *last occurrence

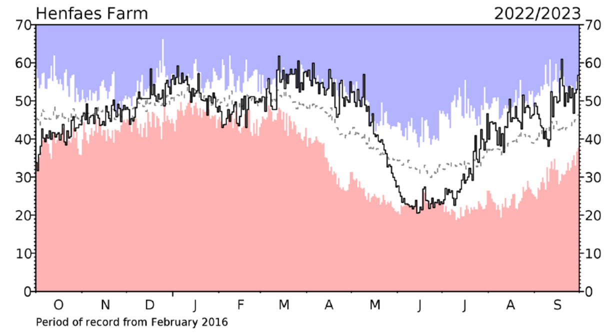
+ excludes Lough Neagh

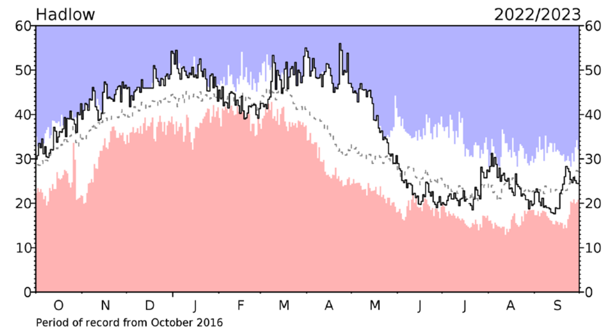
Details of the individual reservoirs in each of the groupings listed above are available on request. The percentages given in the Average and Minimum storage columns relate to the 1988-2012 period except for West of Scotland and Northern Ireland where data commence in the mid-1990s. In some gravity-fed reservoirs (e.g. Clywedog) stocks are kept below capacity during the winter to provide scope for flood attenuation purposes. Monthly figures may be artificially low due to routine maintenance or turbidity effects in feeder rivers.

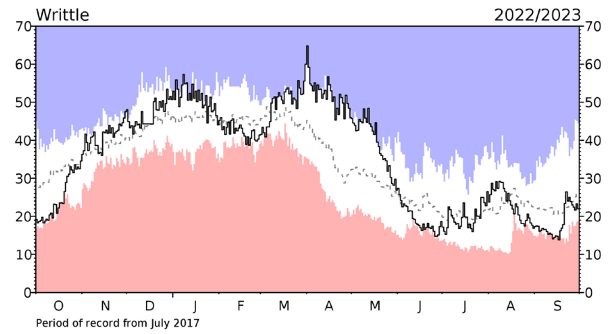
Soil Moisture . . . Soil Moisture

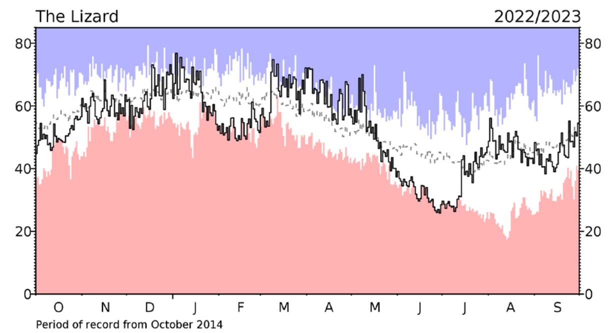












Following a dry start to September, above average rainfall in most of the UK in the second half of the month saw soil moisture levels rise throughout the country except in the south east.

By the end of the month, soil moisture levels increased to near or above field capacity at all COSMOS-UK sites except those in south east England. Several western sites, such as Glenwherry in Northern Ireland and Henfaes in north Wales, were at or close to saturation (some of these sites were much wetter than the expected range, and the data are subject to further review). By contrast, Hadlow and Writtle in the south east returned to average soil moisture levels from below-average dryness in the first half of the month. Some sites, such as the Lizard in south west England, remained within their normal range for this time of year.

Soil moisture data

These data are from UKCEH's COSMOS-UK network. The time series graphs show volumetric water content as a percentage in black together with the maximum and minimum daily values for the period-of-record of the sites. The dashed line represents the period-of-record mean VWC. For more information visit cosmos.ceh.ac.uk.

NHMP

The National Hydrological Monitoring Programme (NHMP) was started in 1988 and is undertaken jointly by the UK Centre for Ecology & Hydrology (UKCEH) and the British Geological Survey (BGS). The NHMP aims to provide an authoritative voice on hydrological conditions throughout the UK, to place them in a historical context and, over time, identify and interpret any emerging hydrological trends. Hydrological analysis and interpretation within the Programme is based on the data holdings of the National River Flow Archive (NRFA; maintained by UKCEH) and National Groundwater Level Archive (NGLA; maintained by BGS), including rainfall, river flows, borehole levels, and reservoir stocks.

The Hydrological Summary is supported by the Natural Environment Research Council award number NE/R016429/1 as part of the UK-SCAPE programme delivering National Capability.

Data Sources

The NHMP depends on the active cooperation of many data suppliers. This cooperation is gratefully acknowledged. A location map of all sites used in the Hydrological Summary can be found on the NHMP website. River flow and groundwater level data are provided by the Environment Agency (EA), Natural Resources Wales - Cyfoeth Naturiol Cymru (NRW), the Scottish Environment Protection Agency (SEPA) and, for Northern Ireland, the Department for Infrastructure - Rivers and the Northern Ireland Environment Agency. In all cases the data are subject to revision following validation (high flow and low flow data in particular may be subject to significant revision).

Details of reservoir stocks are provided by the Water Service Companies, the EA, Scottish Water and Northern Ireland Water.

The Hydrological Summary and other NHMP outputs may also refer to and/or map soil moisture data for the UK. These data are provided by the Meteorological Office Rainfall and Evaporation Calculation System (MORECS). MORECS provides estimates of monthly soil moisture deficit in the form of averages over 40 x 40 km grid squares over Great Britain and Northern Ireland. The monthly time series of data extends back to 1961.

Rainfall data are provided by the Met Office. To allow better spatial differentiation the rainfall data for Britain are presented for the regional divisions of the precursor organisations of the EA, NRW and SEPA. The areal rainfall figures have been produced by the Met Office National Climate Information Centre (NCIC), and are based on the HadUK-Grid 1km resolution gridded data from rain gauges. The majority of the full rain gauge network across the UK is operated by the EA, NRW, SEPA and Northern Ireland Water; supplementary rain gauges are operated by the Met Office. The Met Office NCIC monthly rainfall series extend back to 1836 and form the official source of UK areal rainfall statistics which have been adopted by the NHMP. The gridding technique used is described in Hollis, 2019 available at https://doi.org/10.1002/gdj3.78

Long-term averages are based on the period 1991-2020 and are derived from the monthly areal series.

The regional figures for the current month in the hydrological summaries are based on a limited rain gauge network so these (and the associated return periods) should be regarded as a guide only.

For further details on rainfall or MORECS data, please contact the Met Office:

Tel: 0370 900 0100
Email: enquiries@metoffice.gov.uk

Enquiries

Enquiries should be directed to the NHMP:

Tel: 01491 692599
Email: nhmp@ceh.ac.uk

A full catalogue of past Hydrological Summaries can be accessed and downloaded at:

http://nrfa.ceh.ac.uk/monthly-hydrological-summary-uk